Jets & MET
with CMS Calorimeter

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Brief history of HCAL/JetMet Simulation & Software

'94	CMS TP	- requirements	SSCSIM (physics) new CMSIM (single particle) Test beam sim. - Geant3 -
'95	Test Beam	- understand test beam data - verify GEANT3 - optimize HCAL geometry Heavy Higgs/SUSY (high Et>50GeV)	
'96	Test Beam		
'97	HCAL TDR ECAL TDR		
'98	TRK TDR	- optimize dead material distribution in ECAL and Tracker Light Higgs / single top (Et <50GeV & fwd jets & b-tag) - jet energy correction - met energy correction → L1 algorithm and rates ttH (multi jets, b-tag)	CMSIM (physics) → Reco - fotran -
'99			CMSIM → Reco – fortran - → ORCA
'00	Trig TDR		
'01			
'02	DAQ/HLT TDR	- HLT jets/met (low & high lumi.) Met → SUSY, extra-dim. Jets Et~1-2TeV → compositeness	
'04	PHYS. TDR		OSCAR – Geant4 – (slow/fast) → ORCA
'06	1st Run		

Main Issues

Many physics analyses require

- low E_T jets:

  from top, W, Higgs
  from WW fusion

  part of signal
  background rejection (e.g. jet veto)

- High luminosity

  pile-up energy
  low ET jets from overlapping events
  fake jets due to pileup.

- τ jet
- b jet (tag)

- Correct energy scale from low E_T to very high E_T
- Better resolution for Jet/MET

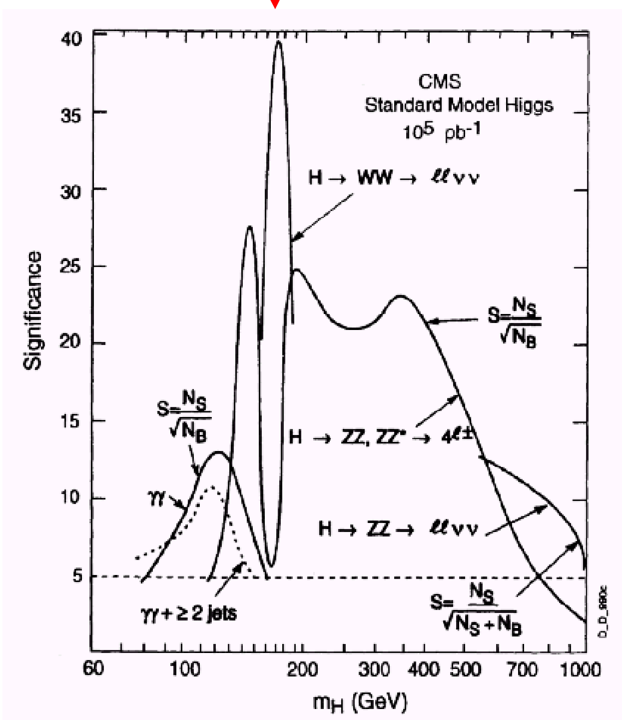
E_T range

20GeV-2TeV

H(170) -> WW -> $l\nu l\nu$

CMS Note 1998/089
(with FNAL group)

1.24pb

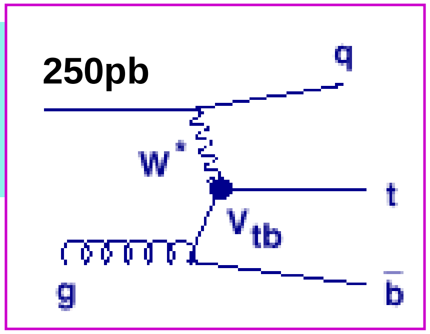


Event Selection:
(total 11 cuts)
two opposite sign leptos
- PT cuts (20GeV,10GeV)
- angle between two leptons
jet veto
- ET>20GeV in $|\eta|$<2.4: removed
Mass (WW)
- M > 140GeV

Background:
tt -> (Wb)(Wb) ->($l\nu$b)($l\nu$b) 62.5pb
WW(continum) -> $l\nu l\nu$ 7.4pb

Results:
- **number of events (5fb^{-1})**
  H / tt / WW = 54 / 35 / 28
- **good channel for discovery**
- **background: need good understanding**
- **jet veto: important.**

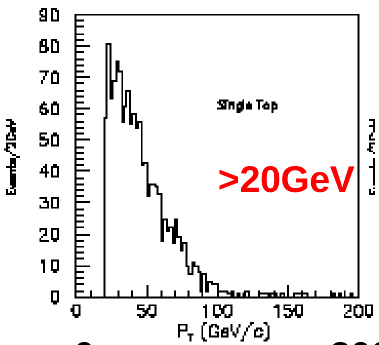
Single Top - Kinematics



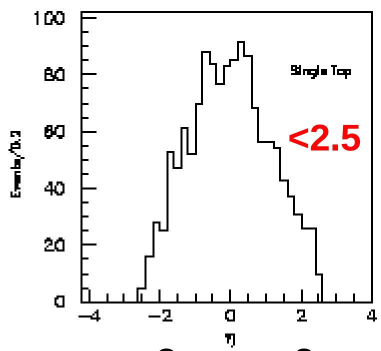
CMS Note 1999/048
(with FNAL group)

Measurement of
- V_{tb} / top decay properties / background to new physics

P_T (lepton) η

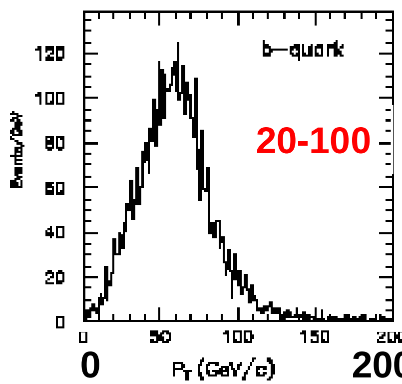


0 200

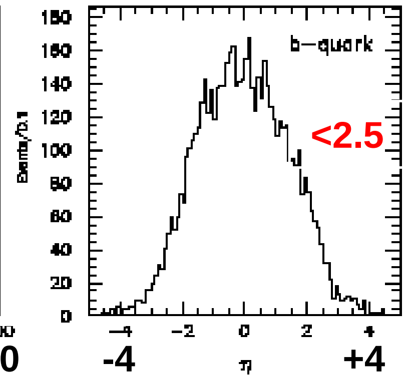


-2 +2

E_T (b-quark) η

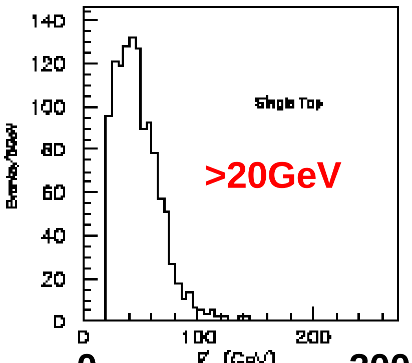


0 200



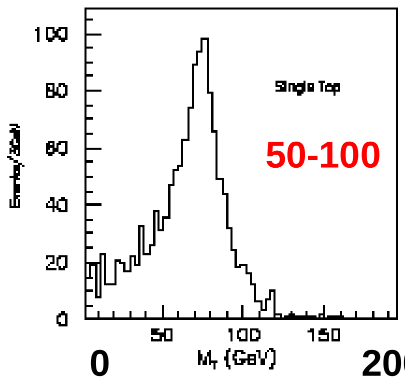
-4 +4

MET



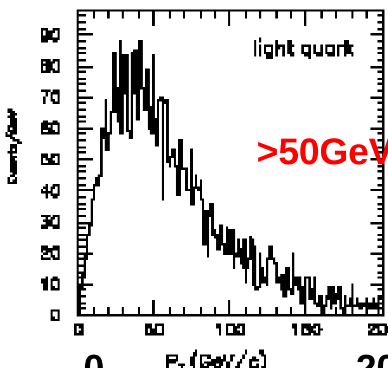
0 200

M_T ($l+\nu$)

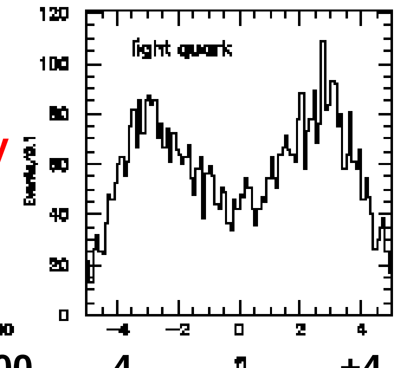


0 200

E_T (tagging jet) η 2.5-4.0



0 200

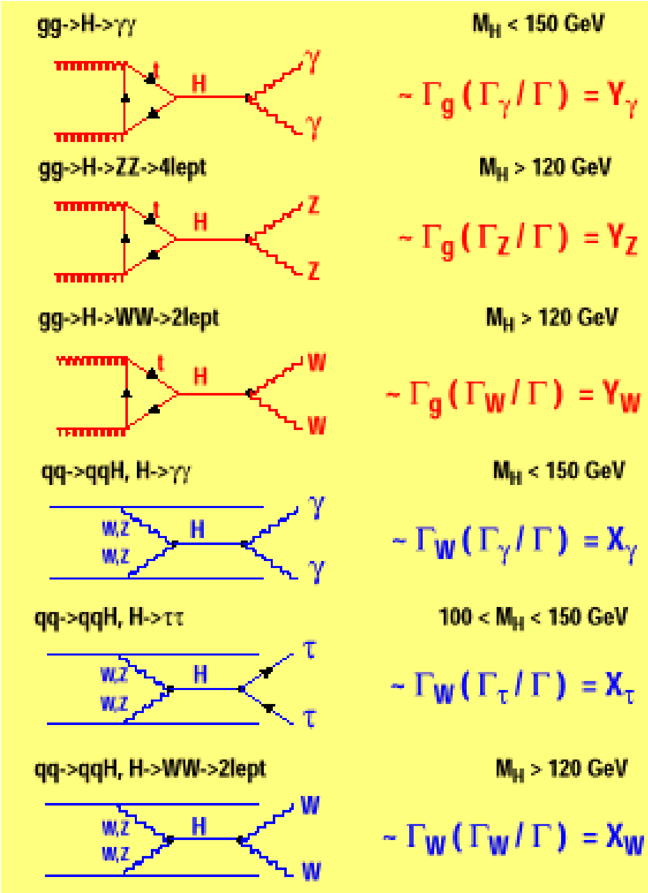


-4 +4

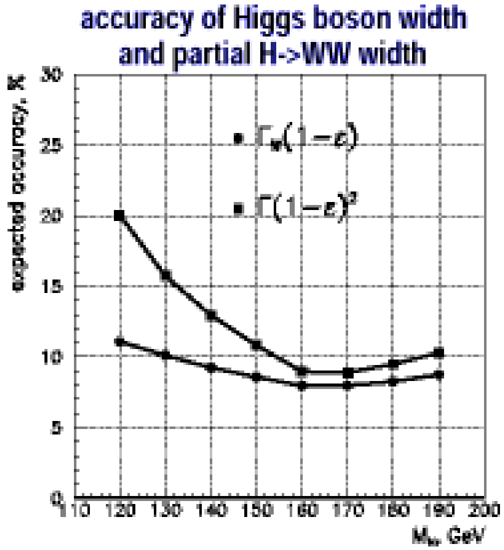
(need looser cuts for qqH)

Forward tagging jets & Higgs Couplings measurement

D.Zeppenfeld, R.Kinnunen, A.Nikitenko, E.Richter-Was, Phys.Rev.,D62(2000) pp13009



Accuracy expected with 200 fb^{-1} of data with ATLAS+CMS detectors at LHC



- measure $H\gamma\gamma$, $H\tau\tau$, Hgg couplings at 10 % level
- hWW coupling ($|\sin(\beta-\alpha)|$) can be measured at 5% level

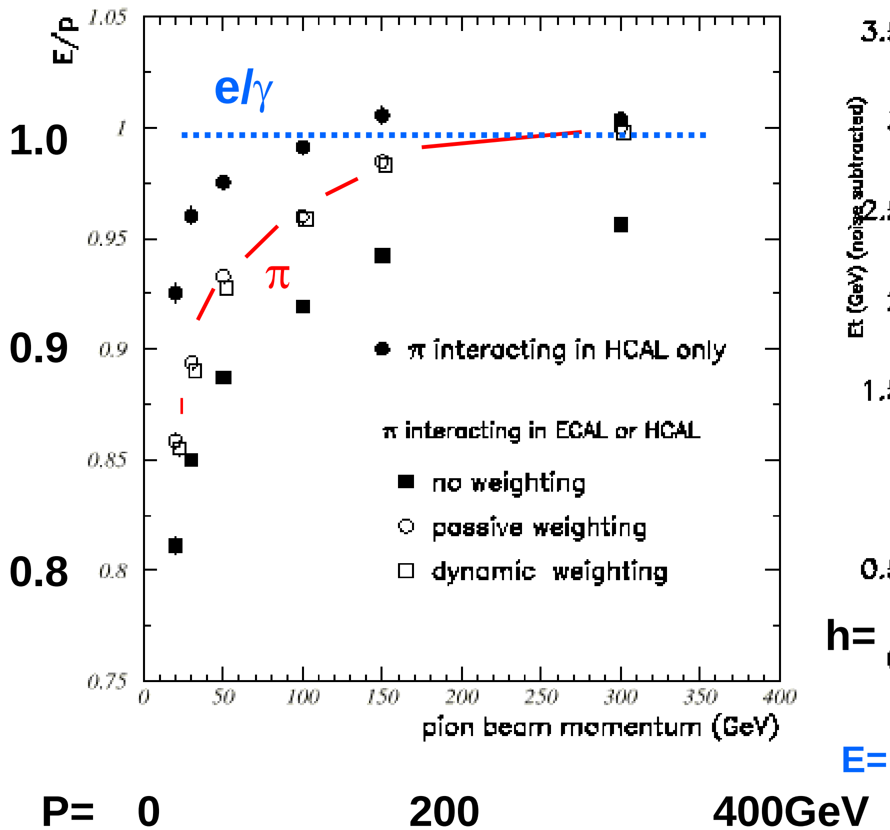
Although σ(VBF)~σ(GF)/6, VBF process may play a big role in measurement of higgs properties in addition to discovery potential.

Pion Response: Linearity

ECAHL+HCAL: Non compensating calorimeter

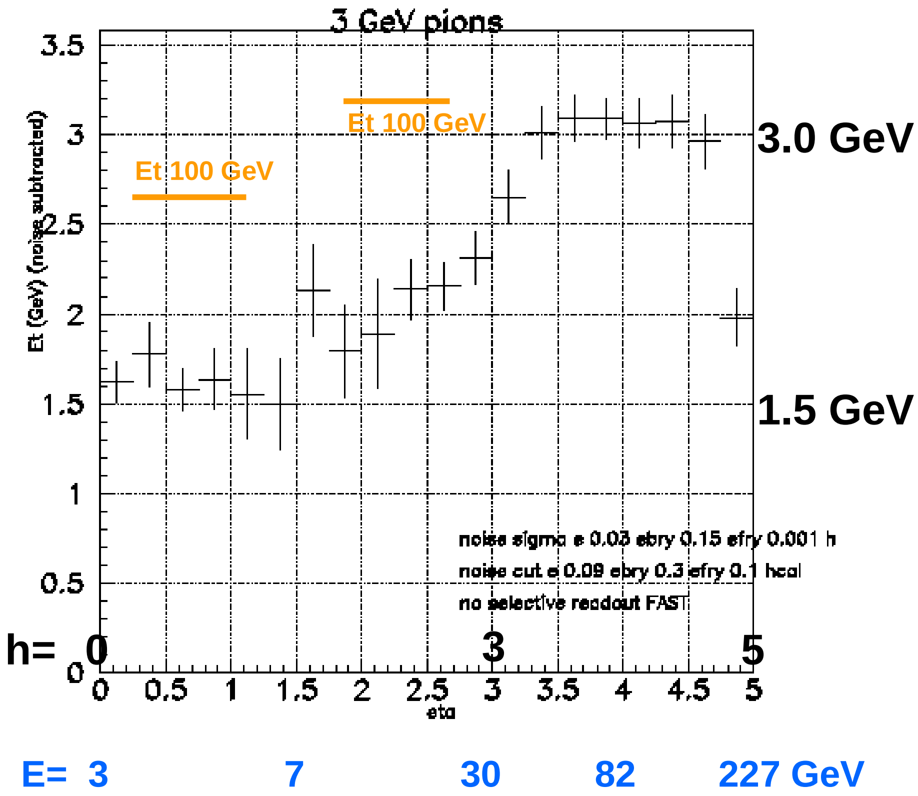
96'H2 Teast Beam Data

E=EC + α x H1 + H2 +HO



CMS Simulation

ET=3 GeV pion in 0<|η|<5



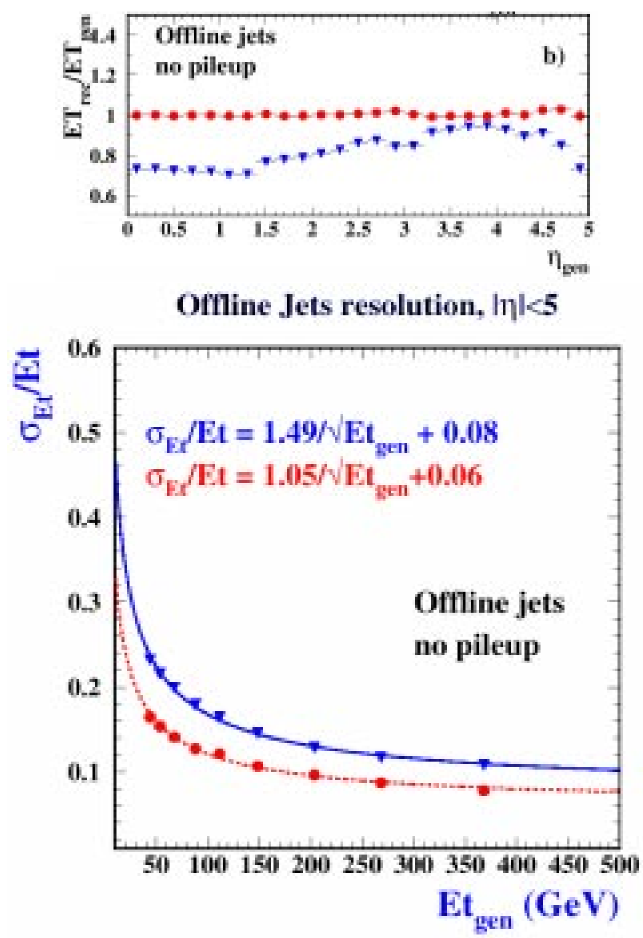
Jet Response and Correction #1

CMS IN 2001/001
(with Krokhotine, ITEP)

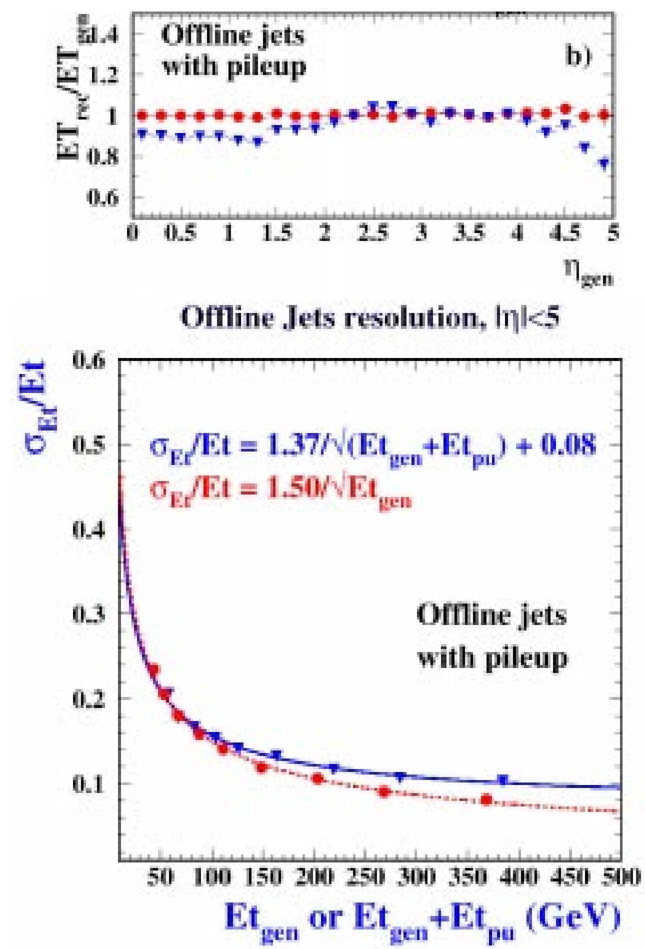
Et-eta dependent correction for QCD jets

$Et(corr) = a + b \times E_T(rec) + c \times E_T(rec)^2$

No pileup



With pileup



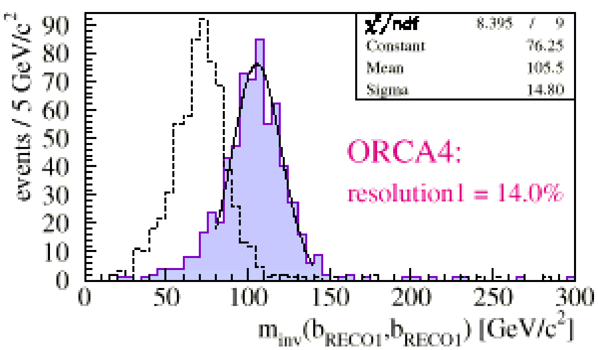
Dijet Mass Resolution

No pileup

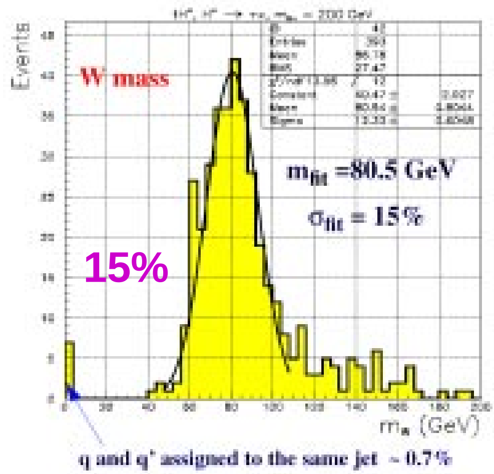
With pileup (tH$^+$ sample)

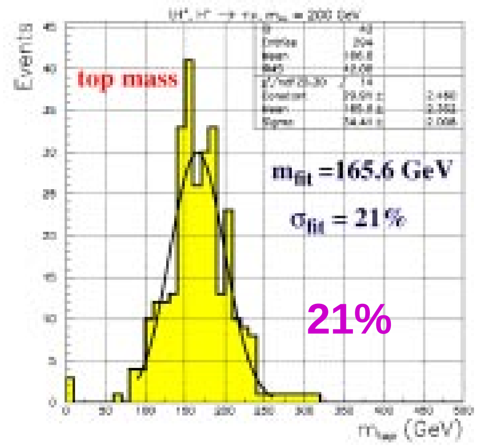
W(jj) **Top(jjj)**

M(bb) in ttH



Before correction





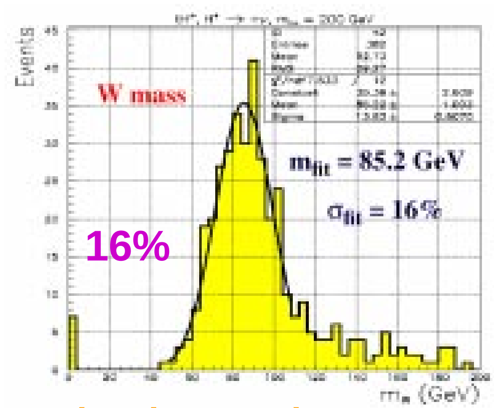
After correction

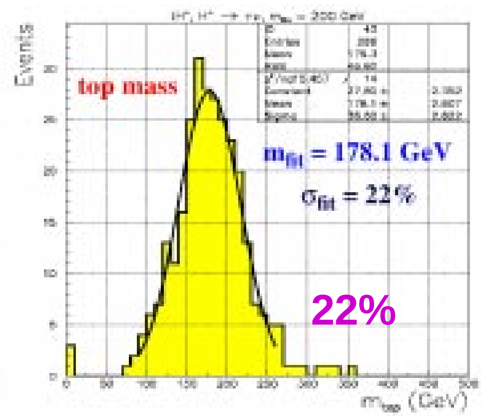
Jet energy correction

without: 19%

with: 14%

CMSJET 15%

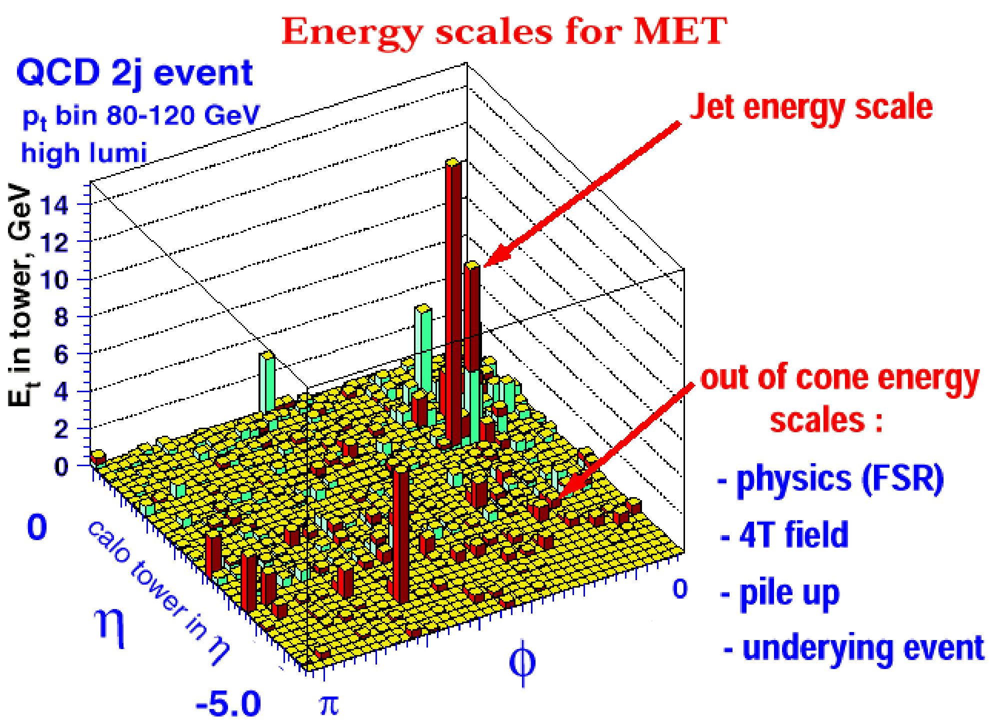




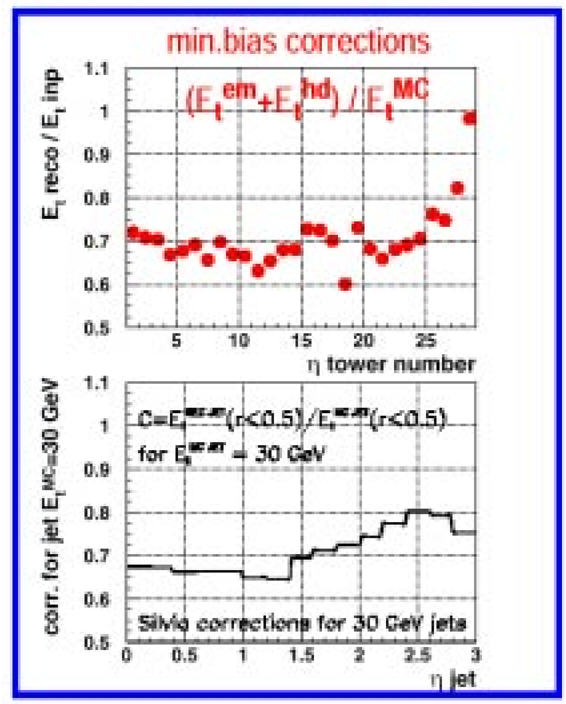
(S.Arcelli & V.Drollinger) (R.Kinunnen)

MET

CMS Note in preparation
(with Nikitenko, CERN/ITEP,
Kinunnen, Helsinki)



Out of cone corr. uses weights for jet(30GeV) corr.



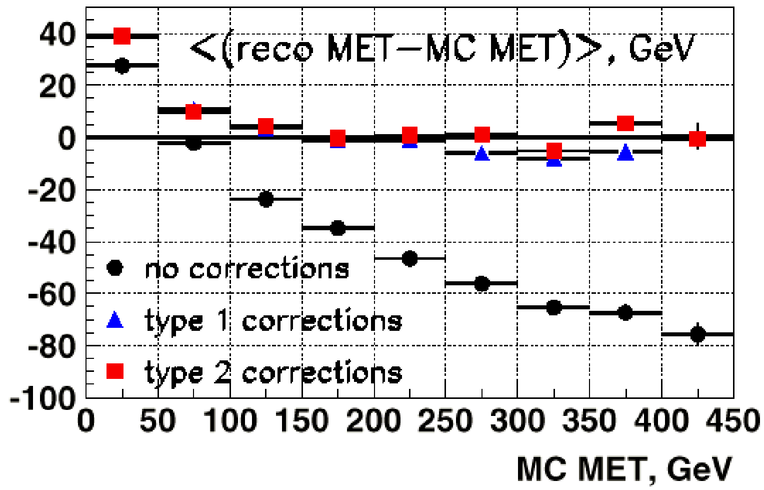
Corrections

Type 1: Jet corr.

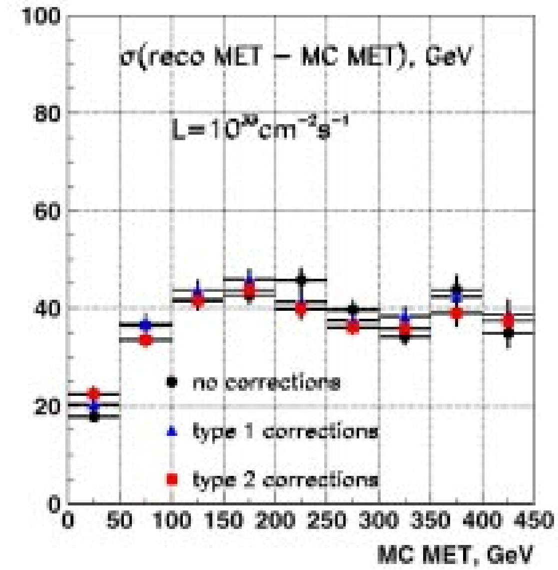
Type 2: Jet corr. + out of cone corr.

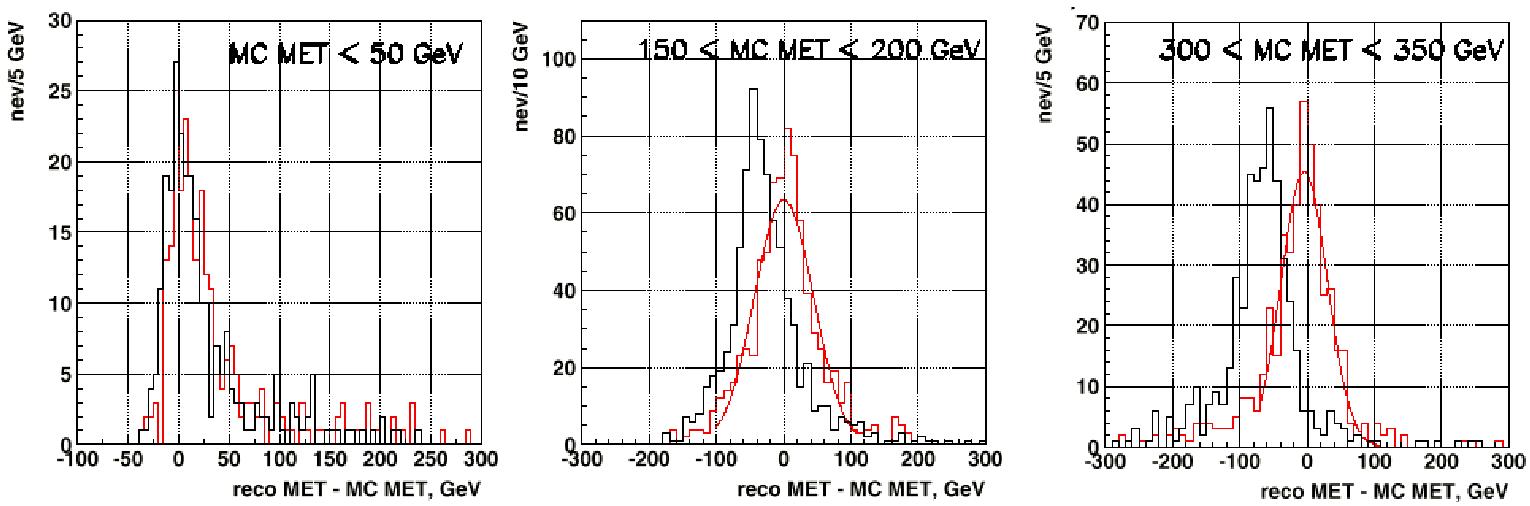
Corrected MET for mSUGURA Jets+MET at low lumi

Mean offset



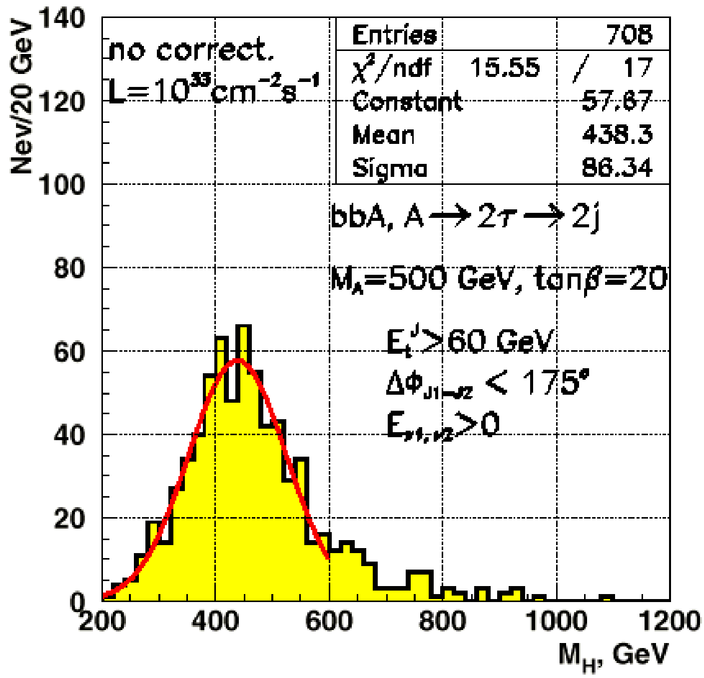
σ



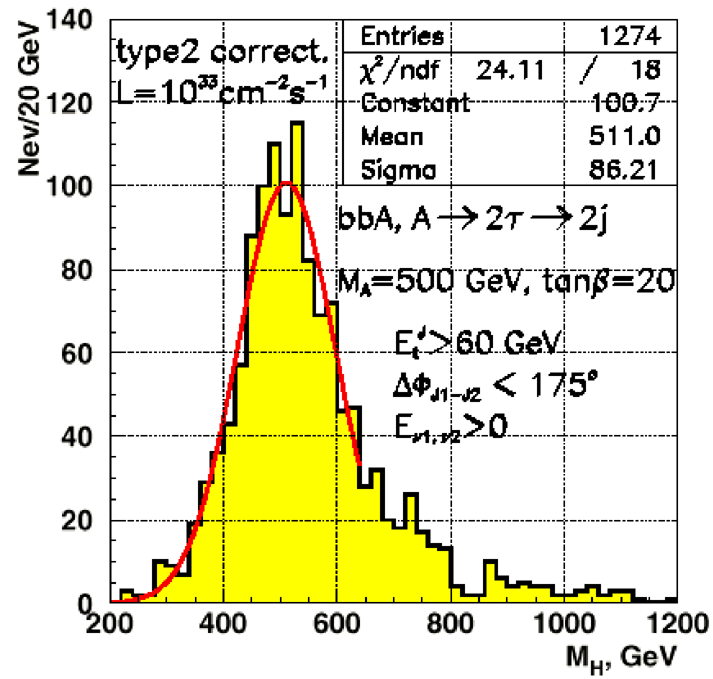


Higgs mass in bbA, A→2τ→2j

before correction



after correction



bbA, A->2τ->2j	no corrections	type1 corrections	type2 corrections	CMSJET
$\langle M_H \rangle$	438.3 GeV	500.3 GeV	511.0 GeV	500.0 GeV
$\sigma / \langle M_H \rangle$	19.7 %	18.9 %	16.8 %	13.4 %
ε_{reco} (corr.) / (no corr)	1	1.53	1.80	

Jet correction method #2

CMS Note in preparation
(with MSU, ITEP group)

Jet Corr. #1

α x (EC+HC)

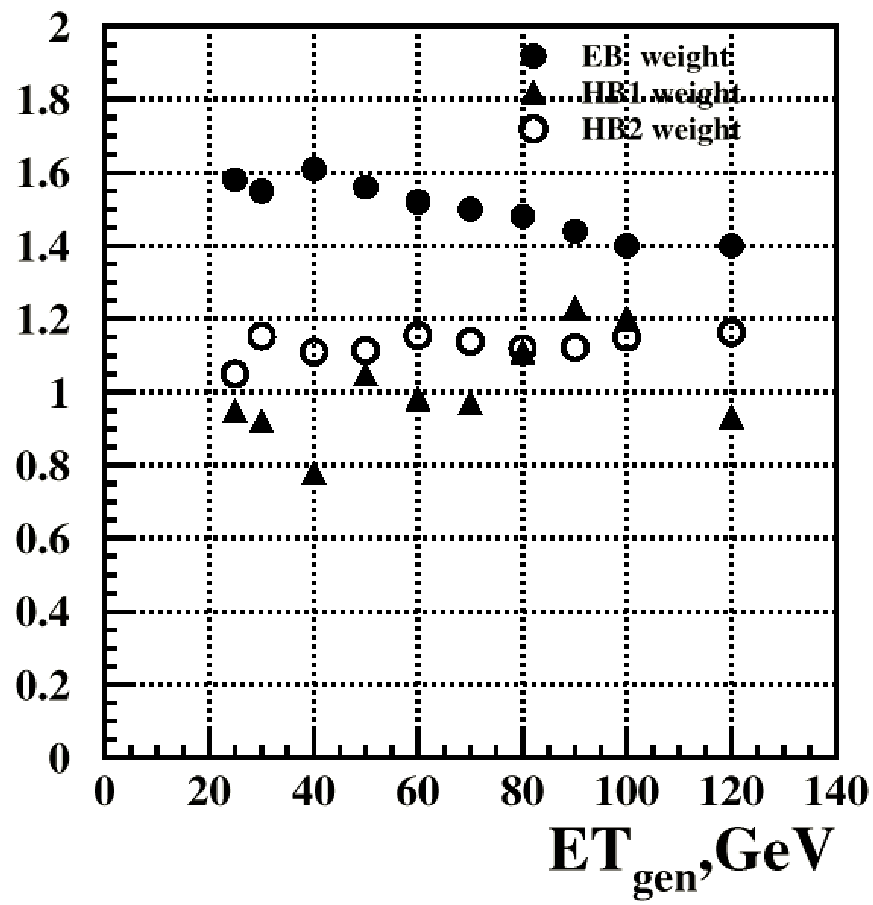
- corr. for jet energy scale
- α depends on jet(Et,η)

Jet Corr. #2

α x EC + β x H1 + γ x H2

- optimize jet resolution (and jet energy scale)
- α, β, γ depends on jet(Et,η)

Optimized weights by #2
0.0<η<0.4



Jet Correction method #2

Table 1: Optimum weights and energy resolutions for ET=80 GeV jets

eta range	eb	hb1	hb2	ee	he1	he2	RESOLUTION CMSIM120 weights + energy corrections	RESOLUTION optimum weights
0.0 - 0.4	1.48	1.12	1.12				0.143	0.136
0.4 - 0.8	1.49	0.95	1.19				0.141	0.134
0.8 - 1.1	1.49	1.08	1.19				0.144	0.137
1.25-1.45	1.47	0.98	1.40	1.89	1.26	1.54	0.136	0.133
1.7 - 2.0				1.44	1.04	1.15	0.134	0.128
2.0 - 2.4				1.32	1.03	1.15	0.123	0.120

Table 3: Optimum weights and energy resolutions for ET=120 GeV jets

eta range	eb	hb1	hb2	ee	he1	he2	RESOLUTION CMSIM120 weights + energy corrections	RESOLUTION optimum weights
0.0 - 0.4	1.40	0.93	1.16				0.124	0.119
0.4 - 0.8	1.41	1.13	1.13				0.132	0.126
0.8 - 1.1	1.40	1.16	1.16				0.125	0.121
1.25-1.45	1.44	0.82	1.37	1.85	0.55	1.73	0.125	0.119
1.7 - 2.0				1.37	0.91	1.14	0.122	0.116
2.0 - 2.4				1.29	0.70	1.17	0.117	0.113

Correction Method #3 (single pion)

(D.Green)

$$E = 1/e_E (e/\pi)_E R_E + 1/e_H (e/\pi)_H R_H$$

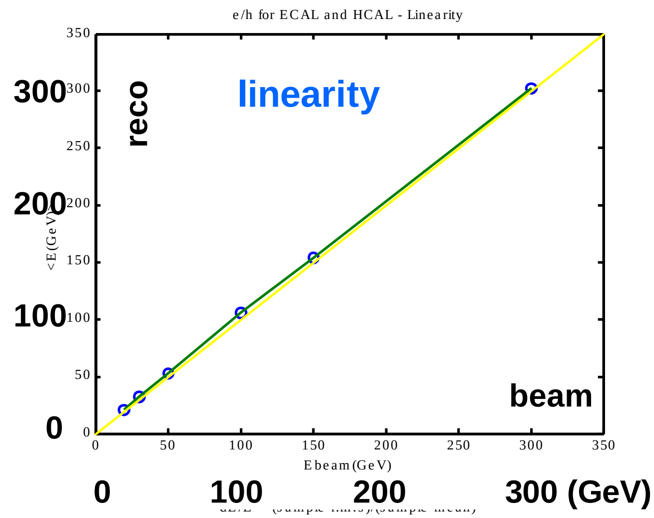
$$F_o = E_e / E \sim 0.11[\ln(E)]$$
$$e/\pi = e/h/[1+(e/h-1)F_o]$$

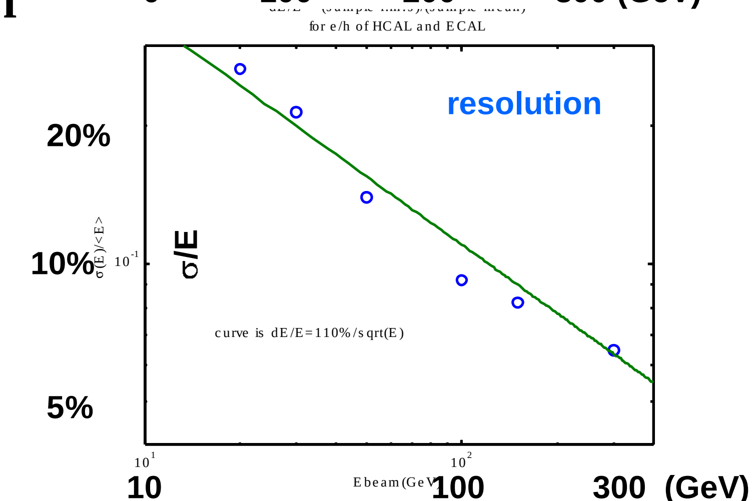
$(e/h)_{HCAL} \sim 1.39$ (NIM paper)

To find e/h for ECAL, measure e/pi at different energies for showers where there is a substantial energy (> 30% of the beam energy) in ECAL.

$(e/h)_{ECAL} \sim 1.60$

Linearity is restored to a few %. The resolution is Gaussian to a high level of accuracy with ~ NO constant term and a 120% stochastic coefficient

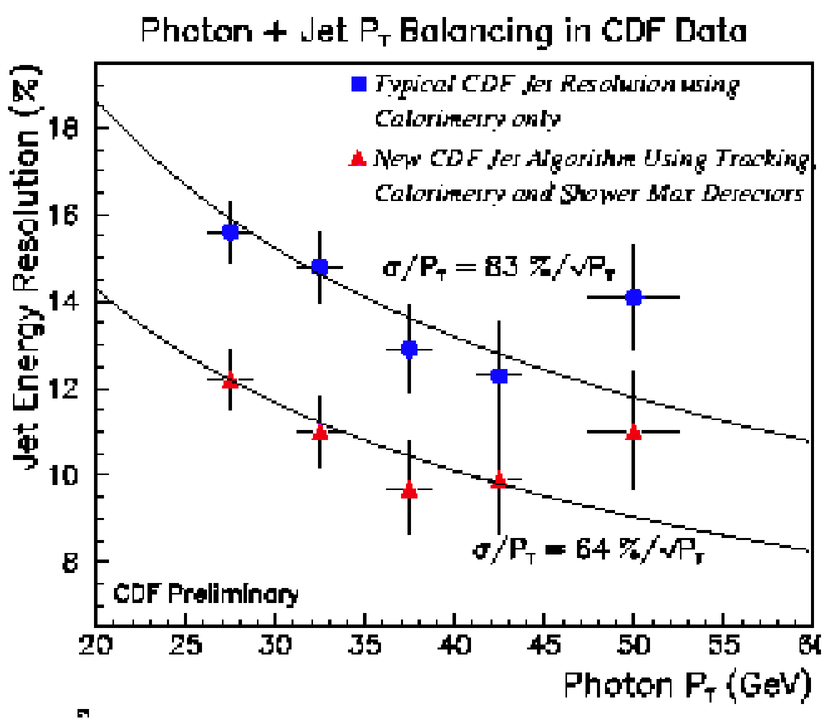




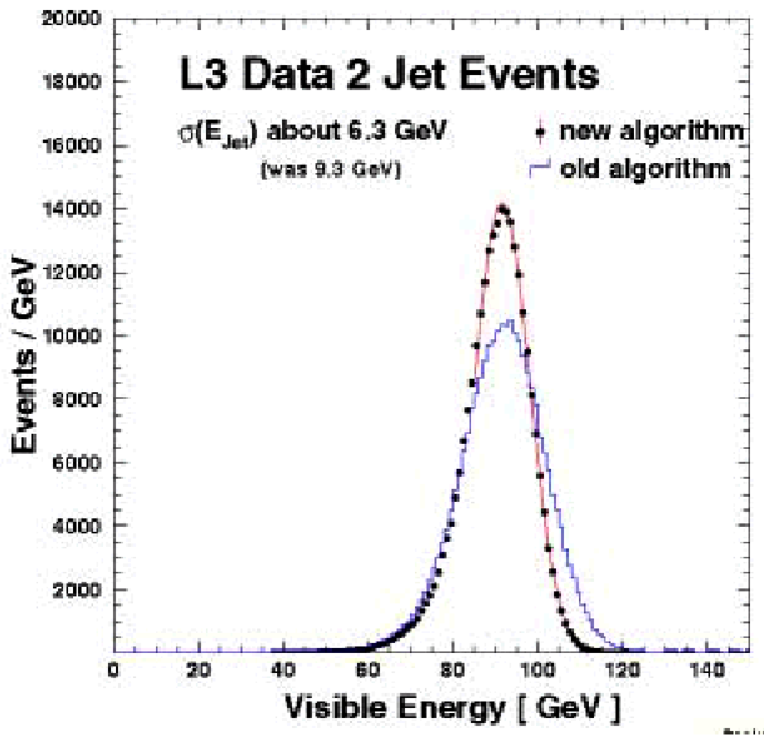
Next: identify em cluster and had cluster in jet using transverse shower shape (in crystals) and reco-ed tracks and apply this to had cluster.

Improvement of jet energy resolution with tracks

CDF

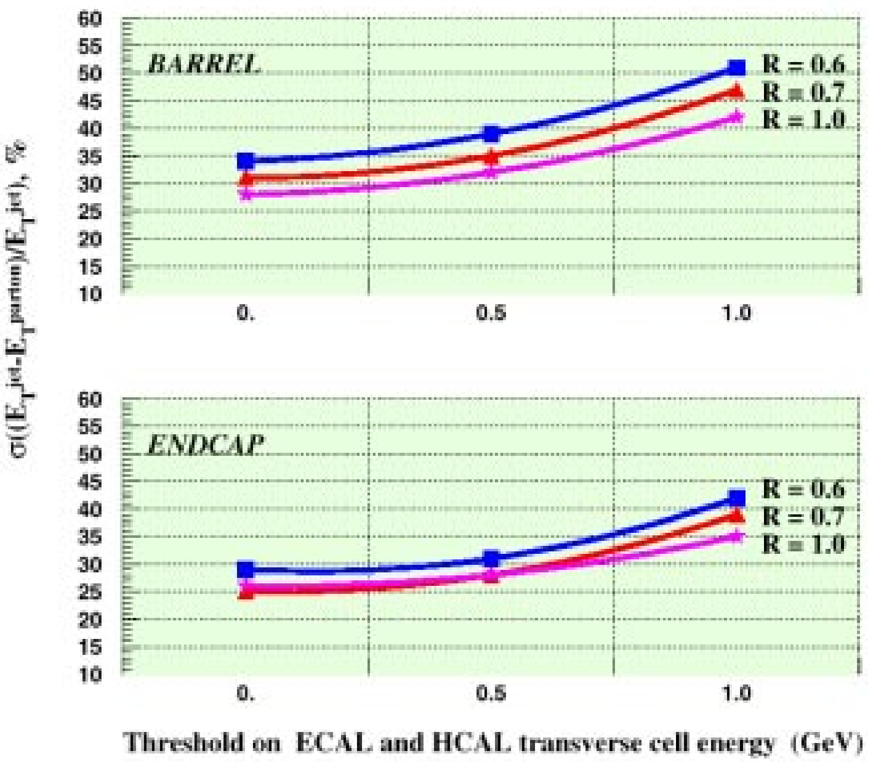


L3

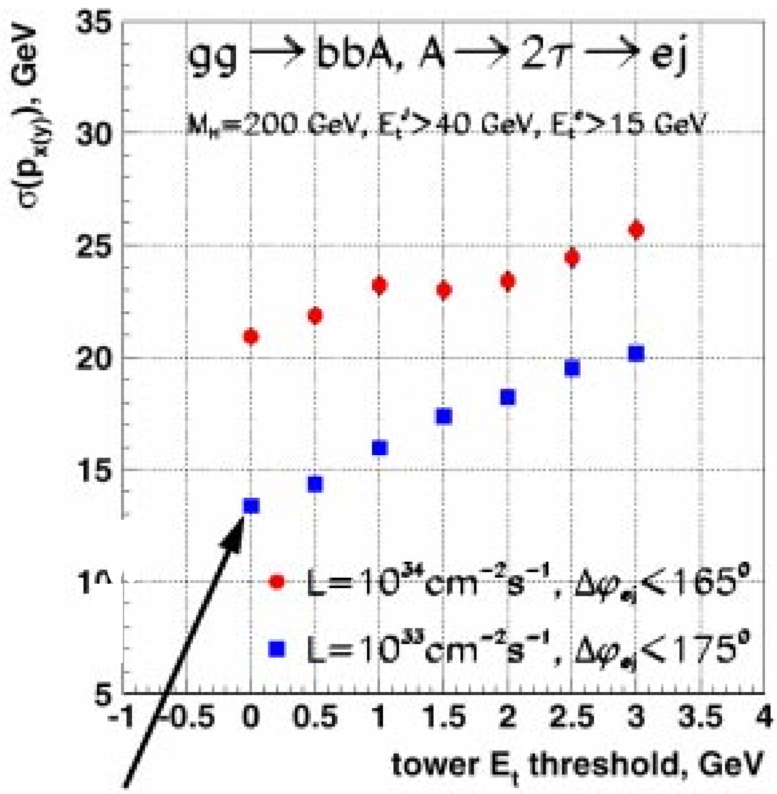


Effect of Threshold on low E_T jet and MET

20GeV parton jet @ 10E34



MET

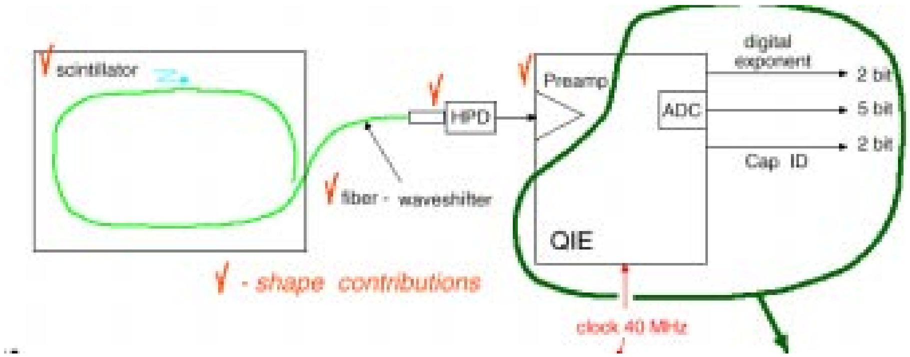


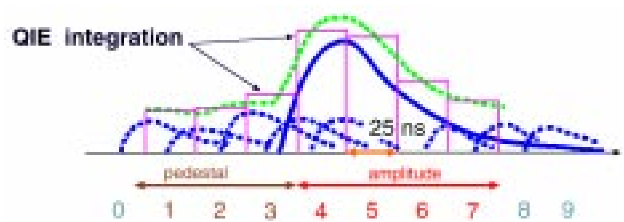
Lower threshold is better!

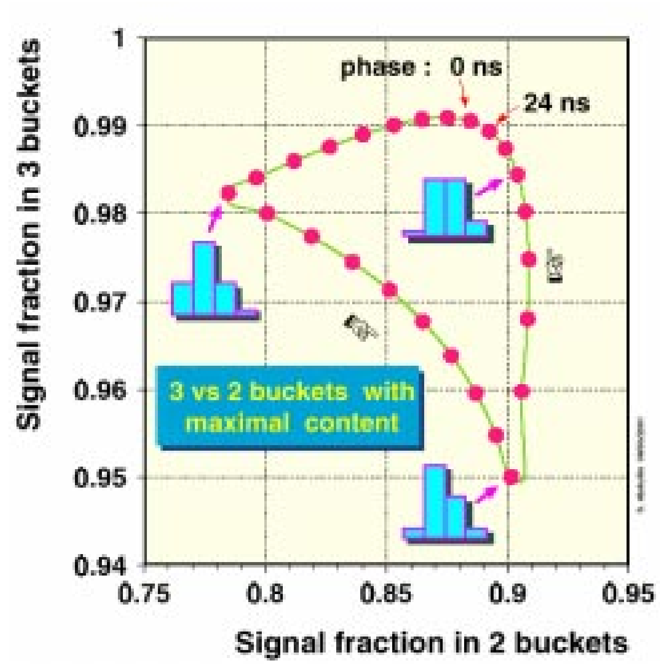
Electronics noise and occupancy define the threshold.
>> aim at 0.5GeV/tower @ 10E34

Front end electronics simulation

(S.Abdoullin)







(Original scheme)

$$E = \Sigma\,(\text{Signal buckets})_i - \Sigma(\text{pre buckets})_j/n$$

Electronics noise 200MeV/25nsec/ch → 500MeV/(3+3) buckets/ch

→ New scheme: 2 buckets for signal
separate pedestal events

Algorithm for L1 through Offline (1)

L1 – calorimeter only (coarse segmentation)

- **Resolution improvement**
  - Equalize calorimeter response with simple correction
    - **a x (EC+HC), a depends on jet(ET,h)**
    - **a x EC + b x HC, a,b depends on jet(ET,h)**
- **Fake Jets/Pileup jets rejection**
  - Threshold cut on a central tower in jets (seed cut)

L2 – calorimeter only (fine segmentation)

- **Resolution improvement**
  - Better energy extraction from ADC counts
  - Em/had cluster separation using transverse shower shape in crystals
- **Fake jet/Pileup jet rejection**
  - Use of transverse shower shape

Algorithm for L1 through Offline (2)

L3 – calorimeter plus pixel

- **Resolution improvement**
  - Pileup energy subtraction
    - **Estimation of energy flow from pileup events using pixel hits/tracks.**
- **Fake jets/Pileup jets rejection**
    - **Vertex information and jet pointing using pixel hits/tracks.**

Offline – calorimeter plus fully reco-ed tracks

- **Resolution improvement**
- **Fake jets/Pileup jets rejection**
  - → Jet and MET will be reconstructed with Tracks, EM clusters and HAD clusters.
  - → All tracks down to E_T~ 700MeV have to be reconstructed at 10E34!
- **Physics correction – e.g. correction for IFR/FSR.**
  - → In-situ calibration!